DOCUMENT RESUME

ED 188 887 SE 031 131

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TITLE Why Women Avoid the Study of Mathematics: A Longitudinal Study. Final Report.
INSTITUTION ABT Associates, Inc., Cambridge, Mass.
SPONS AGENCY National Inst. of Education (DHEW), Washington, D.C.
PUB DATE 30 Nov 79
CONTRACT 400-77-0099
NOTE 48p.

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Attitudes; Bias; Decision Making; *Elective Courses; Elementary Secondary Education; Females; Grade 6; Grade 9; Grade 12; Longitudinal Studies; *Mathematics Anxiety; *Mathematics Education; *Program Attitudes; *Sex Differences; Sex Role; Sex Stereotypes; *Student Attitudes; Surveys; Womens Education
IDENTIFIERS *Mathematics Education Research

ABSTRACT

The goals of this study were to trace the development of students' desire to participate in mathematics or to avoid it whenever possible, and to examine closely differences between boys and girls in reasons for enrollment or avoidance. To trace this decision-making process, information was collected from nearly 2,000 students. In the 1976-77 school year, these students were enrolled in the sixth, ninth, and twelfth grades, and the younger two groups were followed through the 1977-78 and 1978-79 school years. A wide variety of topics were covered with students in search for the reasons they used to decide about taking more courses in mathematics. Studied were the background factors of socioeconomic status and ability; students' attitudes toward mathematics as an easy, creative, enjoyable, and useful field; and students' interpretation of the clues given by their social milieu concerning the appropriateness of their studying mathematics. All students were given a yearly questionnaire, and, in addition, a number of girls were interviewed. Among the conclusions reached were: (1) Students have reasonably ambitious plans to continue their study of mathematics; (2) Boys plan to study more mathematics than girls; and (3) There is a clear decline in students' liking and enjoyment of mathematics over time. (Author/MK)

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WHY WOMEN AVOID
THE STUDY OF MATHEMATICS:
A LONGITUDINAL STUDY

Final Report

November 30, 1979

Submitted by:

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To:

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Contract No. 400-77-0099

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SE 031 131

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EXECUTIVE SUMMARY

Introduction

From the conception of this study in 1976, its goals have been to trace the development of students' desire to participate in mathematics or to avoid it whenever possible, and to examine closely differences between boys and girls in reasons for enrollment or avoidance. The rationale behind such a study is that too many students, particularly girls, are dropping mathematics in high school as soon as they can. They do not realize that their lack of mathematical preparation will restrict their job opportunities, keeping them out of many of the higher-paying jobs and seriously limiting their opportunities for growth and advancement in other jobs. We need to know why students decide to quit taking mathematics, in order to reverse the process and encourage them to keep studying the subject.

To trace this decisionmaking process, information was collected from nearly 2,000 students in three New England school systems. In the 1976-77 school year these students were enrolled in the sixth, ninth, and twelfth grades, and the younger two groups were followed through the 1977-78 and 1978-79 school years.

A wide variety of topics were covered with students in the search for the reasons they used to decide about taking more courses in mathematics: the background factors of socioeconomic status and ability; students' attitudes toward mathematics as an easy, creative, enjoyable, and useful field, and their interpretation of the clues they were given by their social milieu concerning the appropriateness of their studying mathematics. This latter topic included asking about the degree of encouragement they felt they were receiving from teachers, parents, and peers; the degree to which they felt it was appropriate for females as well as males to study mathematics; and the

degree to which they felt they shared any personality characteristics with mathematicians. All students were given a yearly questionnaire on these topics, and in addition a number of girls were asked to talk at length about them in interviews.

Summary of Literature

The research literature repeatedly demonstrates that women participate in mathematical activities less often than men beginning with optional high school mathematics courses and continuing through college courses and majors, graduate school programs, and jobs in quantitative areas (Admissions Testing Program, 1977; American Mathematical Society, 1975; Centra, 1974; Kreinberg, 1979; McCarthy & Wolfle, 1975; National Assessment of Educational Progress, 1978; Sells, 1974).

Possible explanations for differential participation include each of the topics suggested above as reasons to explore in this study. For each factor there is some evidence that boys and girls differ and that the factor is related to participation in mathematics. For example, a group of researchers have examined student attitudes about the usefulness of mathematics (Aiken, 1974; Armstrong, 1979; Fennema & Sherman, 1977; Haven, 1971; Hilton & Berglund, 1974; Husen, 1967; Sherman & Fennema, 1977; Wise, 1978). Most found sex differences, but these differences were not always replicated in every site or school in each study. In the Fennema and Sherman work, for one, sex differences were only apparent in two of their four high schools. But each of the researchers who checked found significant positive correlations of students' attitudes toward the usefulness of mathematics and enrollment in optional mathematics courses (Armstrong, 1979; Haven, 1971; Sherman & Fennema, 1977).

In the present project the explanatory factors proposed in other studies will be examined simultaneously so that one factor can be compared to the next to see what sorts of variables differentiate boys and girls and which are the most powerful predictors of participation. Results from the study can then be transposed into suggestions for school systems on how to encourage more girls to participate in optional mathematics.

Methodology

This three-year study began with students in the sixth, ninth, and twelfth grades. The sixth graders were followed through seventh and eighth grades, and the ninth-graders through tenth and eleventh grades. The twelfth-graders were followed after graduation through the use of postcards which could not solicit complete information. At the end of the study, though, such complete information was available on the entire range of grades from the sixth grade through the end of high school.

Sample. All students were enrolled in three New England school systems. One is located in a rural area, one a suburb of a large city, and one encompasses a small city. In the first year of the study, about 100 children from each of the three selected grades from each school system were tested. These students comprise the primary sample for the study and were followed for the maximum amount of time possible. In the second year of the study, all of the remaining children in the appropriate grades in these systems who were not in the primary sample were also tested. They comprise a comparison sample for the study.

Table 1 summarizes descriptive data on the samples. A total of 816 children comprise the primary sample, and we have a full three years of data on 275 middle school students and 239 high school students. About 8 percent of the sample represent minority groups, while 46 percent of the eighth- and

Table 1

Description of Sample

Primary Sample (Eighth- and Eleventh-Graders)

Grade Level (1978-79)[a]	Eighth			Eleventh			Total
School District[b]	A	B	C	A	B	C	
Number	91	95	89	90	70	79	514
Mean Age (Years)	13.07	13.25	13.23	16.08	16.26	16.19	
Sex (Male/Female)	41/50	63/32	43/46	35/55	26/44	31/48	239/275
Percent Minority	0	12	8	2	17	9	8
Percent Working Class	67	57	15	66	68	6	46
Percent Mothers Employed	60	66	50	71	60	51	60
Percent College-Bound	85	65	94	72	67	96	80

Comparison Sample

Grade Level (1978-79)	Eighth			Eleventh			Total
School District	A	B	C	A	B	C	
Number	76	87	78	26	62	55	384
Mean Age (Years)	13.12	13.06	13.17	16.12	16.19	16.22	
Sex (Male/Female)	38/38	44/43	34/44	15/11	28/34	34/21	193/191
Percent Minority	0	14	10	0	8	11	8
Percent Working Class	49	56	6	52	67	7	39
Percent Mothers Employed	65	71	45	62	72	53	61
Percent College-Bound	68	68	97	89	63	95	78

Primary Sample (Twelfth-Graders)

Grade Level (1976-77)	Twelfth			Total
School District	A	B	C	
Number	98	102	102	302
Mean Age (Years)	16.96	17.04	17.24	17.15
Sex (Male/Female)	60/38	43/59	40/62	143/159
Percent Minority	--not assessed--			---
Percent Working Class	46	42	3	29
Percent Mothers Employed	55	60	35	50
Percent College-Bound	66	79	98	82

[a] Background data were collected in all three years of the study. The most recent data are presented here because they apply to the sample in its final form--that is, after attrition had taken place.

[b] A is a rural school district, B a small city, C a suburb of a large city, all in New England.

eleventh-graders in the primary sample and 29 percent of the twelfth-graders are from working class families. These percentages are each below the national averages of 17 percent of children under 15 years of age who belong to minority groups and 60 percent working class families (Women's Bureau, 1975 Handbook on Women Workers). On the other hand, the number of working mothers approximates that in the U.S.: among the eighth- and eleventh-graders, 60 percent of the mothers are working and among the twelfth-graders, 50 percent, while the national average is 56 percent.

While the primary sample differs somewhat from the nation at large, it is reasonably representative of these school systems' populations. The children in the primary and comparison samples from school systems B and C do not differ in any way that might be expected to affect the results of the study. And in school system A, the only potential problems lie in the fact that the primary sample has a somewhat larger proportion of children from working-class backgrounds than the comparison sample and may have children with more ambitious plans for the future.

Procedure

In the fall of each year of the study, all students in the appropriate grades in the three school system were given an extensive questionnaire covering a range of areas of potential interest: family background; course preferences and enrollment plans; expected liking of future courses; career plans; attitudes toward coursework; and distance between students' self-perceptions and their perceptions of mathematicians and writers. Attitude questions asked about English and mathematics, so that the mathematics results could be placed in perspective. On the second year questionnaire several essay questions were added so that students could express their opinions about mathematics in their own words. In each year, students took from 25 to 40 minutes (about one class period) to fill out the questionnaire.

In the spring of the second and third years of the study, 48 girls were interviewed about their views of mathematics. Each was selected because her plans to study mathematics changed considerably from the past year to the present one; half wanted to take more mathematics in the present than they had in the past, the other half less. Findings from the interviews usefully supplement the questionnaire results.

With parental permission, we collected students' IQ test scores, mathematical and verbal achievement scores, and, for high school students, space relations scores. All three systems gave the Differential Aptitudes Test (DAT) to eighth-graders, so scores from this instrument sufficed for high school students. IQ scores for the middle school students came from a wide variety of IQ tests, achievement scores from the Stanford Achievement Tests or the Iowa Test of Basic Skills (mathematics and verbal scores); no space relation scores were available.

Questionnaire Measures

Family Background. These questions concerned age, sex, ethnic background, school, father's and mother's employment and education, and number and order of siblings. For analysis purposes, all non-Caucasian children were classed as "minority," and father's occupation was used in rating the socio-economic status of the family unless no father was present.

Course Plans. Questions in this area differed for middle school and high school students. The younger students were asked to circle the course they would prefer to take in each of nine pairs of courses. In each instance, one member of a pair was mathematics, physics, or chemistry, and the other English, social studies, or a foreign language. Course Plans, in this case a measure of preference, was scored from 0 to 3 depending on the frequency of selection of mathematics. For the older group, students were asked to write down the number of

courses they intended to take in each of the school's departments by the time of graduation. Course Plans was scored as number of years beyond two (which was required in each high school) that the student planned to take or had taken, ranging from 0 to 3.

Liking of Courses. All students were asked to rate a list of courses from 1 to 5 according to how well they thought they would like future courses in that area. They were told to pretend that they didn't know who the teacher would be, only that the course was in a particular subject. On this scale 1 represented "I expect to dislike it very much"; 2 represented "I expect to dislike it somewhat"; 3 represented "I am indifferent"; 4 represented "I expect to like it somewhat"; and 5 represented "I expect to like it very much." All students rated biology, chemistry, English, history, languages, mathematics, and physics.

Career Plans. Students were asked to list their first three choices for a career. Each choice was then rated for the level of education required—0 represented a high school diploma, 1 represented a college degree, and 2 represented an advanced degree—and for its subject area—physical science, natural science, or other.

Attitude and Anxiety Scales. Items from four pairs of attitude scales were meshed to form an attitude inventory in the first year of testing, and items from two additional scales were included in the second and third years. In Year 1, the scales described mathematics and English as easy/difficult, creative/dull, useful/not useful, and enjoyable/anxiety-provoking. In Years 2 and 3 additional scales probed the degree of sex-typing of each discipline and perceived encouragement for each discipline from parents, teachers, and peers.

On each item, a student was requested to strongly agree, agree, express uncertainty, disagree, or strongly disagree with the statement. A strongly negative feeling toward a subject (whether this was expressed by strong agreement or strong disagreement with the statement at hand) was coded as 1; a somewhat negative feeling ("agree" or "disagree") was coded as 2; indifference ("uncertain") was coded as 3; a somewhat positive feeling (again, "agree" or "disagree") was coded as 4; and a strongly positive feeling (again, "strongly agree" or "strongly disagree") was coded as 5. The scores for each item were then summed to provide a measure of the student's attitude toward mathematics or English.

The first three pairs of scales were primarily derived from those of Husen (1967) and Fennema and Sherman (1976). One pair of attitude scales (Math is Easy/Difficult, English is Easy/Difficult) contained items about the difficulty or accessiblity of mathematics and English. A second pair (Math is Creative/ Dull, English is Creative/Dull) dealt with the degree to which students see mathematics or English as challenging, interesting, and fun, as well as the degree to which they feel they can contribute their own ideas as opposed to memorizing what others already know. A third pair of attitude scales (Math is Useful/Useless, English is Useful/Useless) dealt with the usefulness of the two subjects for everyday life outside of school and for future job and life plans. In each pair the mathematics scale contained 10 items (five negative, five positive), and the English scale eight items (four negative, four positive).

The fourth pair of scales (Math is Enjoyable/ Anxiety-Provoking, English is Enjoyable/Anxiety-Provoking) were simplified forms of items on the Mathematics Anxiety Rating Scale (Richardson & Suinn, 1972; Suinn et al., 1972) and on the Fennema and Sherman Math Anxiety Scale (Fennema & Sherman, 1976), with parallel items constructed about English. Twelve statements (six positive, six negative) comprised each scale.

The four pairs of scales just described were used in all three years of testing; two other pairs were used only in the second and third years. One of these examined the sex-typing of mathematics and English, and included the Fennema and Sherman (1976) Math as a Male Domain Scale (renamed Math is Open to All/A Male Domain) as well as a comparable measure of English constructed for this study. The point was to determine the degree to which students felt each subject was more appropriate for one sex to study than the other. The other pair (Support/No Support from Others—Math, Support/No Support from Others—English) was designed to assess students' perceived support from parents, teachers, and peers. The items followed a pattern: My (parents, teachers, peers) (expect, do not expect) me to do well in (math, English); My (parents, teachers, peers) (encourage, do not encourage) me in my study of (math, English). Each of these last four scales contained 12 questions.

All 12 attitude scales had high split-half reliabilities, ranging from a low of .59 on Math is Creative/Dull for sixth-graders to a high of .92 on Math is Useful/Useless for eleventh graders. Most reliabilities are between .7 and .9, indicating a great deal of consistency in student responses.

Stereotypes vs. Self-Image. The last set of questionnaire items, given only to tenth- through twelfth-graders, asked students to describe their perceptions of a mathematician and a writer, and then to describe themselves on a series of 21 bipolar items first used by Beardslee and O'Dowd (1961). For each item we computed two distance scores, one between the student's self-rating and his/her rating of a writer, the other between this same self-rating and the student's rating of a mathematician. Finally, for each occupation, these distances were summed across all 21 items. Thus, a smaller sum implies a greater identification with a member of that profession.

Results

Two sets of results will be reported in this section. First, we will present the results from the analysis of the Course Plans variable and the attitude variables, concentrating on grade and sex differences on these measures. Because students were tested each year over a three-year period, multiple analyses were necessary. Means for boys and girls in each of the grades tested in a given year are compared through two-way analyses of variance, and means for the same children tested over the three-year span of the study are compared using analyses of variance with repeated measures for the grade factor.

Second, we will discuss the prediction of students' Course Plans from the variables of socioeconomic status, gender, ability, attitudes surrounding liking of mathematics, the usefulness of the field, and the social factors which impinge on students' work in the field. These predictions were made from multiple regression analyses conducted separately for the sixth through eighth-graders and the ninth- through eleventh-graders.

Students' Course Plans and Attitudes

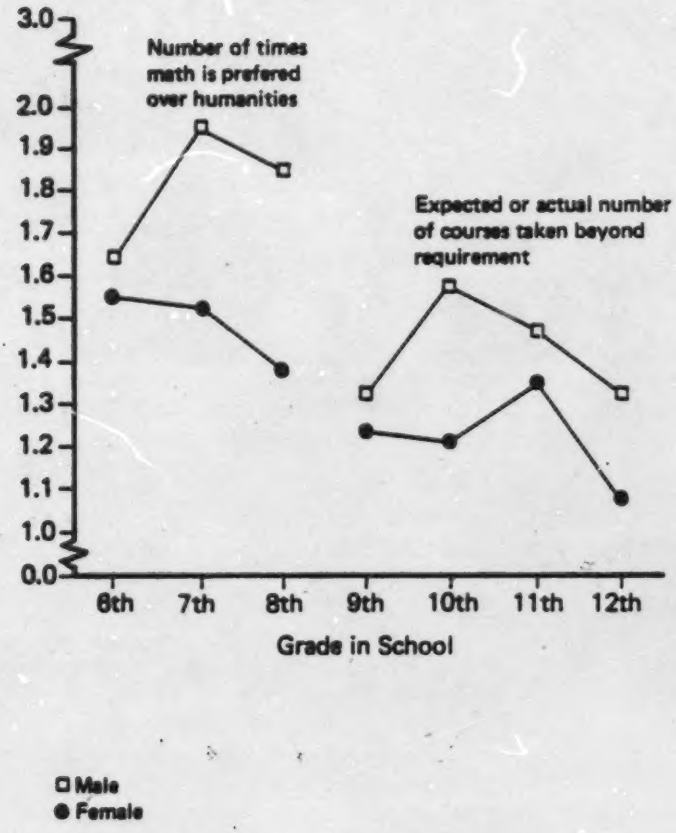
- Students have reasonably ambitious plans to continue their study of mathematics.

Figure 1 reports the results for the Course Plans variables. Students in the sixth through eighth grades state that they would prefer to take mathematics courses over humanities courses half of the time or somewhat more often; high school students plan to take a bit more than one course in mathematics beyond the two years of mathematics that is required.

- There appear to be some grade differences in Course Plans with older students scoring lower than younger students. However, those may well be due to the differences in measures for middle and high school students, rather than to legitimate differences in Plans.

Figure 1

Course Plans in Mathematics



Tables 2 and 3 present the results for the cross-sectional and longitudinal analyses of Course Plans. The former analyses examine differences in the means of the three grades tested in the first year of the study (sixth-, ninth-, and twelfth-graders), and the two grades tested in the second year (seventh- and tenth-graders) and the third year (eighth-and eleventh-graders). The longitudinal analyses are concerned with changes in students from the sixth to the eighth grade and from the ninth to the eleventh grade.

The only significant grade differences in Course Plans appear on Table 2 in the cross-sectional analyses; none are evident on Table 3. The sixth-graders do not change in Course Plans across seventh and eighth grades, nor do the ninth-graders change across their first three years in high school. This suggests that the different measures of Course Plans for the middle and high school students may well be the reason for the grade differences in Table 2.

- Boys plan to study more mathematics than girls, even as early as the seventh grade.

The sex differences in Course Plans are consistently significant in all of the cross-sectional and longitudinal analyses of variance displayed in Tables 2 and 3. In each case girls plan to take fewer mathematics courses than boys. Figure 1 shows the means for Course Plans, and these suggest that girls are less enthusiastic about mathematics as early as seventh grade.

- Most students are neutral or slightly positive in their attitudes toward the pleasure and enjoyment of the study of mathematics.

Most of the means on the measures Like/Dislike, Easy/Difficult, Enjoyable/Anxiety-Provoking, and Creative/Dull are in the neutral to slightly positive range (see Figures 2 and 3). Students say that they like mathematics somewhat, that the subject tends to be easy or at least not overwhelmingly

Table 2

F-Ratios for Main Effects and Interactions for Cross-Sectional Analyses

Scale	Grade Comparisons: 6th/9th/12th			7th/10th			8th/11th		
	Sex	Grade	SxG	Sex	Grade	SxG	Sex	Grade	SxG
Course Plans	5.43*	6.29**	.62	17.48***	12.38***	.10	12.31***	4.85*	3.59
Like/Dislike	.07	9.55***	.46	.04	6.28**	.52	3.51	2.07	.04
Easy/Difficult	18.21***	14.71***	1.17	15.90***	2.98	.05	13.67***	9.62**	.14
Enjoyable/Anxiety-Provoking	18.05***	12.61***	1.47	20.38***	.69	.27	16.48***	4.45*	.52
Creative/Dull	3.00	28.86***	2.18	.27	18.66***	1.11	.84	12.72***	3.81
Useful/Useless	8.06**	13.37***	2.10	3.92*	5.99*	.05	1.61	19.16***	2.21
Support/No Support from Others		NA		7.13**	.32	.08	.73	10.40**	.07
Math as Open to All/ A Male Domain		NA		59.57***	1.54	1.06	82.28***	.27	.16

*$p \leq .05$; **$p \leq .01$; ***$p \leq .001$.

Table 3

F-Ratios for Main Effects and Interactions for Longitudinal Analyses

Attitude Scale	Sex	Grade(linear)	Grade(quadratic)	Sex x Grade$_L$	Sex x Grade$_Q$
Sixth-Eighth Grade:					
Course Plans	11.19***	.03	3.74	4.55*	.08
Like/Dislike	.53	3.93*	.30	1.81	.02
Easy/Difficult	7.85**	1.76	2.86	.66	2.68
Enjoyable/Anxiety-Producing	9.14**	13.28***	3.59	.01	.29
Creative/Dull	.36	11.31***	.04	.08	.08
Useful/Useless	1.47	.15	.00	2.23	.36
Seventh-Eighth Grade:					
Support/No Support from Others	2.65	.64	NA	1.59	NA
Math as Open to All/A Male Domain	38.85***	5.45*	NA	1.02	NA
Ninth-Eleventh Grade:					
Course Plans	9.43**	3.38	.06	3.20	.74
Like/Dislike	.46	1.32	.00	.00	4.24*
Easy/Difficult	12.69***	.62	1.58	.49	.53
Enjoyable/Anxiety-Producing	18.72***	6.49*	2.40	.16	.02
Creative/Dull	5.06*	7.98**	.43	.01	2.18
Useful/Useless	7.39**	17.61***	.75	.99	1.46
Tenth-Eleventh Grade:					
Support/No Support from Others	1.32	7.75*	NA	1.26	NA
Math as Open to All/A Male Domain	51.24***	.02	NA	1.78	NA
Distance of Self-Mathematician	.46	11.40***	NA	.15	NA

* $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$.

difficult, that they often enjoy classes and only infrequently experience anxiety in quantitiative situations, and that they sometimes find it challenging, fun, and an opportunity to be creative.

- There is a clear decline in students' liking and enjoyment of mathematics over time.

This decline is obvious on the four graphs shown in Figures 2 and 3, and is supported by the analyses of variance. First, if you look for consistency in grade differences in these analyses, you can see that the Creative/Dull scale shows clear regular differences. In Table 2 there are highly significant grade differences in all three cross-sectional comparisons and in Table 3 the pattern is continued with two significant linear grade effects on the longitudinal comparisons. Thus, there is a continual and significant decline in students' attitudes toward the nature of mathematical work. As they grow older, students feel more and more that their role in mathematics is to memorize what other people tell them rather than to think things through on their own and contribute their own ideas. Concomitantly, mathematics seems less interesting, challenging and fun the further students get in its study.

Second, in each of the other instances of a significant grade effect, the direction of the effect is consistent: students like mathematics less and less as they grow older; students find mathematics more difficult and more anxiety-provoking with increasing age. So, while the findings are not completely consistent for grade differences in Like/Dislike, Easy/Difficult, and Enjoyable/Anxiety-Provoking, the trends are clear:

(1) There is a decrease in students' liking of mathematics with age on the straightforward index of degree of like or dislike of the field.

(2) With increasing age students are more likely to say that mathematics tends to be difficult and that they may not be able to do advanced work in the field.

Figure 2

The Attitude Factors of Like/Dislike and Easy/Difficult

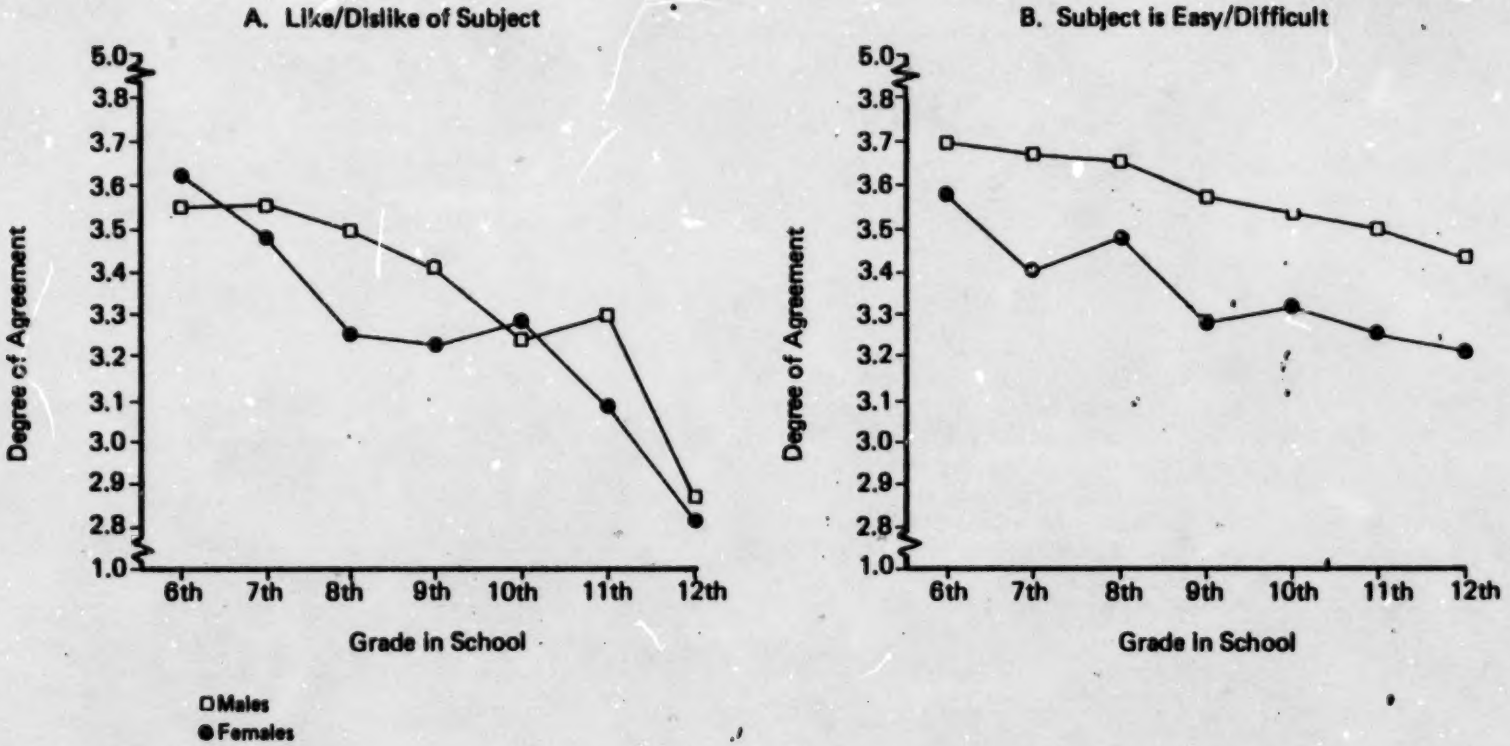
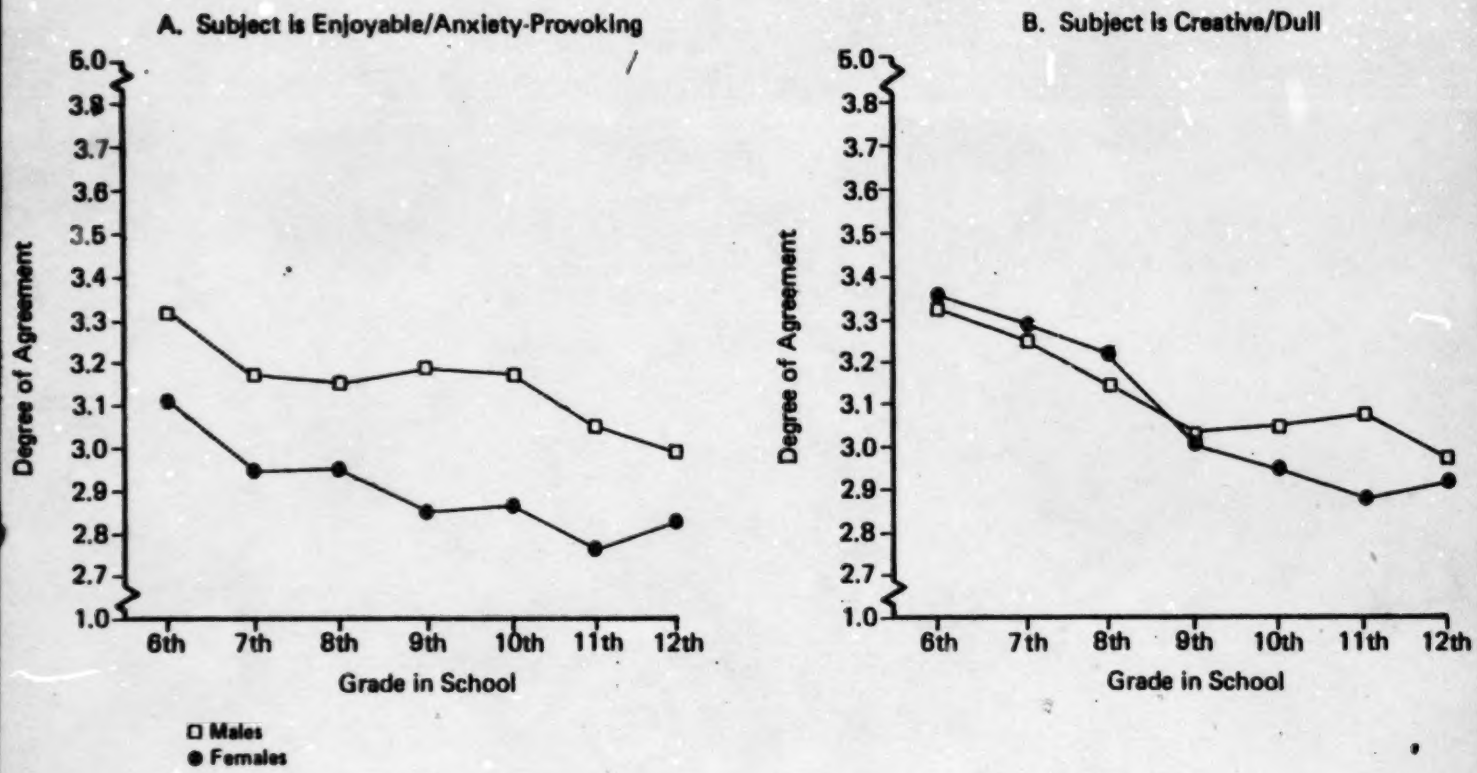


Figure 3

The Attitude Factors of Enjoyable/Anxiety-Provoking and Creative/Dull



(3) As time goes on, more and more students admit to being uncomfortable and even anxious in quantitative situations. More agree that tests are unpleasant, and that it is problematic to find enjoyable lessons in mathematics.

- The decline in attitudes over time which characterizes mathematics does not characterize English. That is, the decline does not reflect a growing dislike of school, but is particular to mathematics (and possibly other subjects).

For each of the scales about mathematics, students were given a parallel scale about English. The trends for English were just the opposite from those for mathematics. Particularly in high school, pleasure in the study of English increased over time; students claimed to like it more, find it easier, more enjoyable, and more creative the farther they went. Thus, the findings about mathematics do not reflect an increasingly negative attitude toward school in general, but rather are specific to certain subjects—one of which is mathematics.

In the question about Like/Dislike of school subjects, we asked students to rate the degree of their liking for a whole set of school subjects: biology, chemistry, English, history or social studies, languages, mathematics, and physics. The relative rankings of each of the subjects is presented in Table 4. In the sixth grade, students placed mathematics high on their list of favorite courses, second only to "science," which for children of this age probably means biology. In the seventh grade, students ranked mathematics second only to chemistry, and in the eighth grade it followed languages and biology. By the ninth grade, however, mathematics lagged behind both English and history/social studies and it never recovered its position of prestige above the major humanities. Hence, students' growing dislike of mathematics accompanies a growing dislike of the physical sciences and stands in opposition to the trend of increasing liking of history and English.

- Girls claim that mathematics is more difficult than boys do and girls rate themselves as more anxious in quantitative situations.

Table 4

Relative Rankings of Liking of School Subjects

6th	7th	8th	9th	10th	11th	12th
Science[a]	Chemistry	Languages	Biology	English	English	English
Mathematics	Mathematics	Biology	English	Biology	History	Biology
Languages	Languages	Mathematics	History	History	Biology	History
English	Biology	English	Mathematics	Mathematics	Mathematics	Mathematics
History	English	Chemistry	Languages	Languages	Languages	Languages
	History	History	Science[a]	Chemistry	Chemistry	Science[a]
	Physics	Physics		Physics	Physics	

[a]In Year 1 of the study, "Science" was used to encompass biology, chemistry, and physics for the sixth graders. "Science" was a combination of the ratings of chemistry and physics only for the ninth- and twelfth-graders.

These results might seem to suggest that girls do not have as high mathematical ability as boys and so do experience more difficulty with the subject. In fact, such a difference was not the case in this sample. The middle school girls had a lower mean percentile score on the standardized mathematics achievement test ($x=41.49$) than the boys ($x=48.03$), but the high school girls' mean ($x=65.25$) was approximately equal to the high school boys' ($x=65.19$), and the main effect for sex in a two-way analysis of variance was not significant.*

Another possibility is that girls are more willing to admit they are having trouble or are anxious than boys when in fact the sexes do not differ. For example, boys may be denying the anxiety they feel because it wouldn't be "masculine" to acknowledge it. Similarly, they may be mustering some bravado and stating they find nothing difficult, rather than admitting that sometimes they, too, find mathematics to be hard.

A third possibility is that girls are more conscious of the image they present in class, and therefore less likely than boys to ask a question which might appear "stupid." This could easily result in their finding the material more difficult and in their being more anxious in class.

- The findings on students' perceptions of the Useful/Useless nature of mathematics are similar to their attitudes about the pleasure of studying the field. That is, the overall means on this scale show that students of all ages think mathematics is a fairly useful subject to know, but the means decrease over time, and girls see mathematics as less useful than boys.

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*The large grade difference is due to the fact that the tests given the middle school students in the sixth grade (those used in this study) had many problems about fractions, and one of the three school systems did not introduce fractions until sixth grade, after the administration of this standardized test. The means reported here are thus accurate reflections of students' achievement levels, but deflated from those that would result from retesting in the spring of the year. Unfortunately, such a testing was not possible within this project.

Figure 4 and Tables 2 and 3 summarize the results for the Usefulness variable. The means for both sexes and all seven grades are well above the neutral score of 3.0, implying that all students see mathematical knowledge as fairly useful to know. The consistently significant grade differences shown on the tables support a decline in perceptions of Usefulness over time, though the graph indicates that the decline is not monotonic. Girls increase slightly in middle school; boys increase slightly at the beginning of high school. In addition, sex differences only appear in two of the cross-sectional analyses and in the longitudinal analysis of high school students. Hence, we may conclude that the degree to which students think mathematics is useful tends to decrease with age, particularly in high school, and that high school girls see mathematics as less useful than do high school boys.

The girls who were interviewed in the third year of the study provided some insight into the reasons for the decline in the perceived usefulness of mathematics over time. They were almost unanimous in their feeling that mathematics would be useful for some aspect of their lives outside of school, and when asked to mention these aspects, they suggested figuring out family budgets, balancing check books, filling out income tax forms, and doing the weekly shopping. All of the examples required only the skills of arithmetic, none the more advanced knowledge provided in high school mathematics. As one might expect, a very small percentage of students wished to pursue professional careers related to mathematics, so that mathematics was not seen as useful for specific career plans. In fact, high school algebra and geometry were only seen as useful for the further pursuit of school mathematics.

- Boys and girls alike feel they are receiving some positive support from parents, teachers and peers for their study of mathematics but the amount of perceived support seems to be less in high school than in middle school.

Figure 4

The Pragmatic Factor of Usefulness

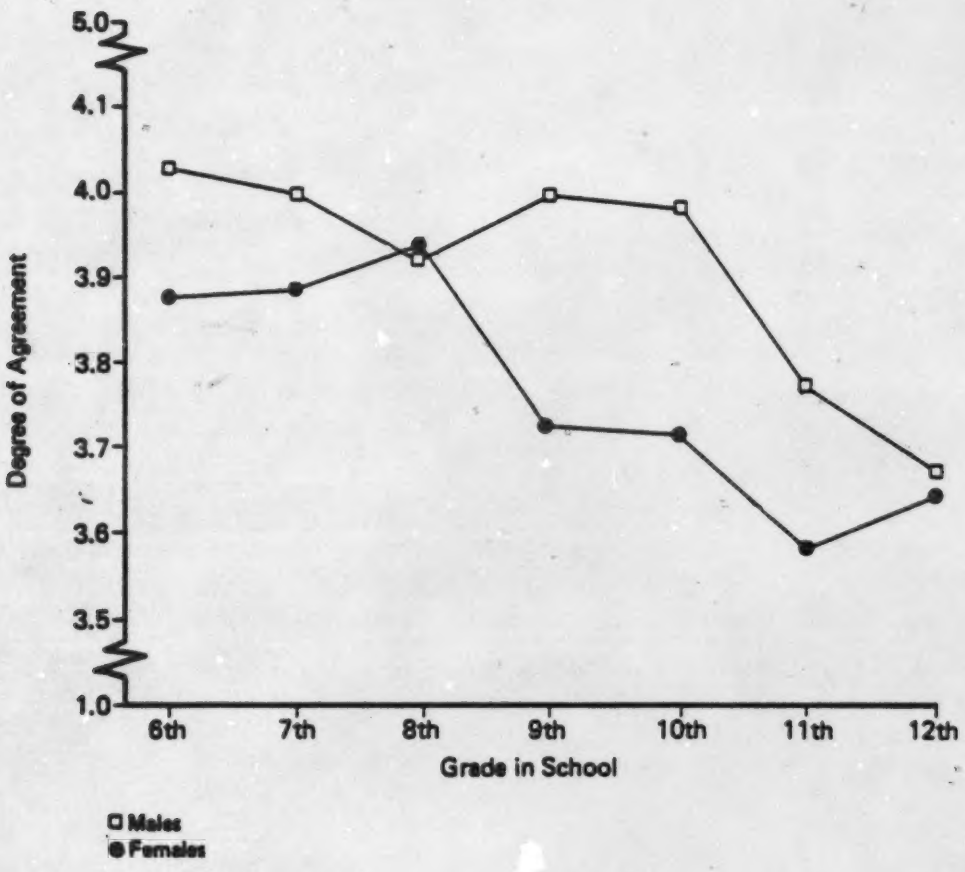


Figure 5A displays the means for the social factor of perceived support from others for work in mathematics. All means are above the neutral score of 3.0. The analyses of variance summarized on Tables 2 and 3 indicate significant grade differences in the cross-sectional analysis of eighth- versus eleventh-graders and in the longitudinal analysis of tenth- and eleventh-graders, suggesting a decrease in support across the high school years. And there was only one sex difference—in the cross-sectional analysis of the seventh- and tenth-grade scores. In this case females felt they had less support than males felt they had. Thus, there is little evidence from this measure of the social milieu that boys and girls are encouraged differentially in mathematics, and little evidence that encouragement differs for the grades below eleventh. This does not mean that the sexes actually receive identical treatment, but it does imply that boys and girls do not believe that the significant people in their environment are treating them very differently.

- Most students feel that mathematics is an appropriate subject for both sexes to study, though females are much more adamant in this opinion than males.

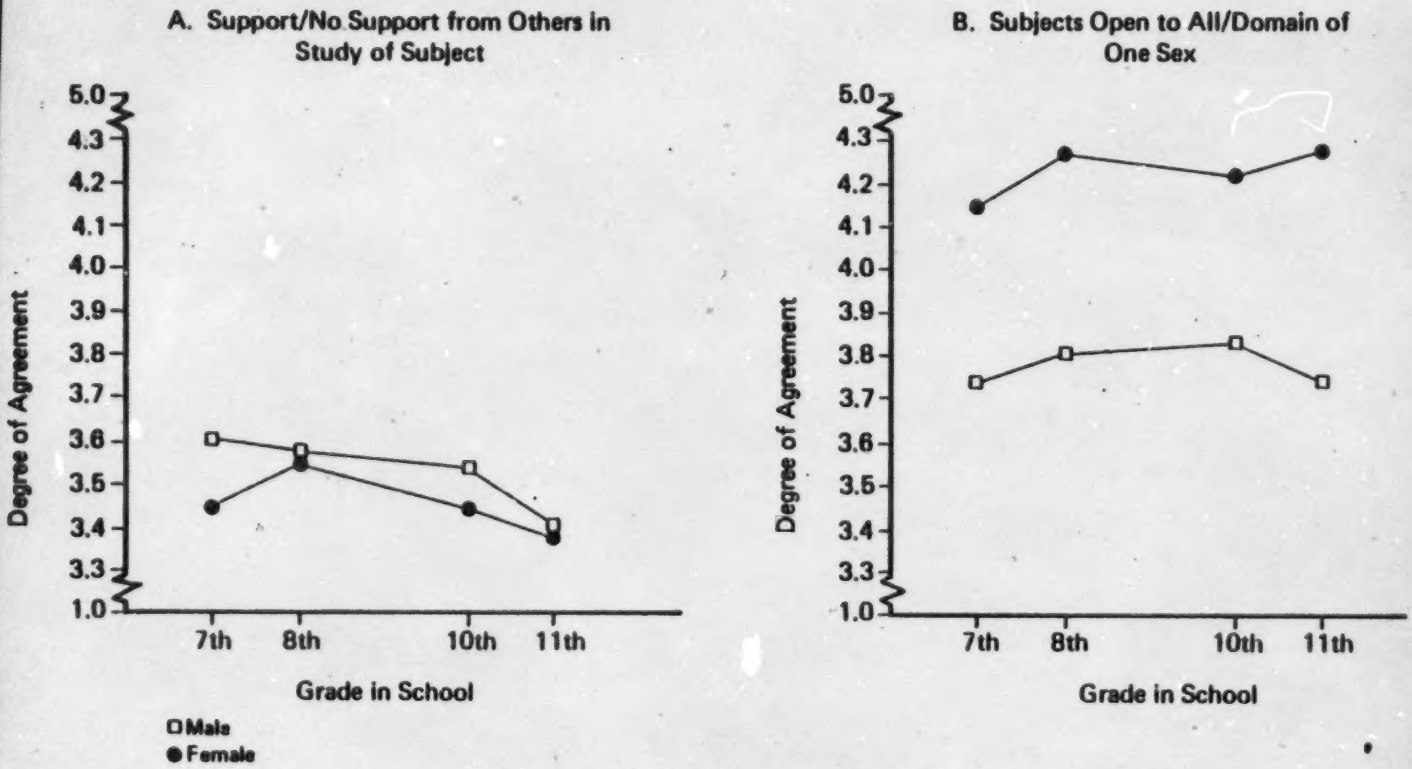
The means plotted on Figure 5B indicate that all students think mathematics is appropriate for both sexes. The tests of significance summarized in Tables 2 and 3 show that there are no grade differences in thoughts about the appropriateness of mathematics for both sexes, as is apparent on the graph, but there are huge and consistent sex differences. Girls are always more certain that mathematics is appropriate for everyone.

The reasons for the lack of grade differences and the strong sex differences may be that this scale is tapping an opinion which all of our society knows is required—you are supposed to say that women and men are equally competent in all fields, whatever your age and actual beliefs, whatever

Figure 5

The Social Factors of Encouragement from Others and

Sex-Typing of Mathematics



your behavior would seem to imply. Girls, in particular, may be responding to the questions on this scale with what they feel are appropriate "liberated" answers.

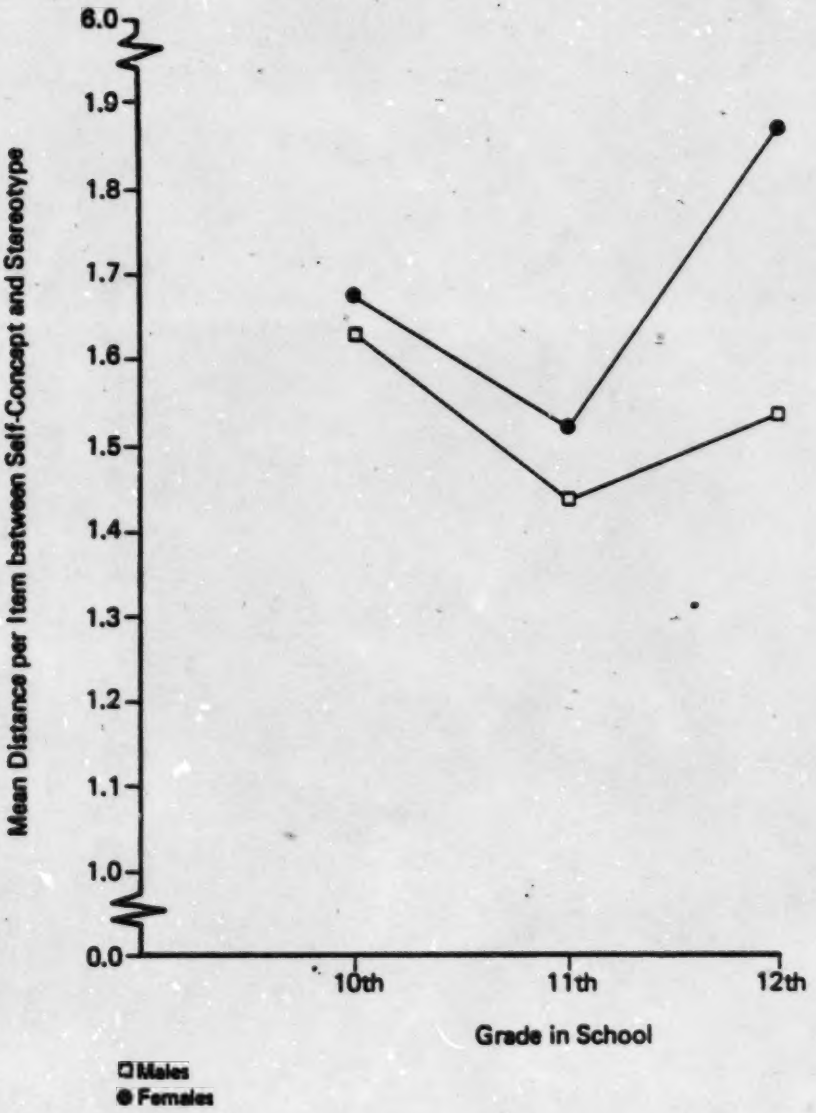
It may also be that these students firmly hold the belief that mathematics should be appropriate for both sexes, and that women can be as good at mathematics as men. At the same time, they may recognize that fewer women are known as geniuses in mathematics and fewer and fewer women will be in their mathematics classes as they get older. Girls' conclusion for their own behavior from these conflicting messages may logically be that they, of course, could choose to study more mathematics, but won't. Thus, this measure may not be tapping a central reason for participating in or avoiding mathematics, but only a belief peripheral to the issue.

- Students feel fairly close to mathematicians in a series of personality characteristics, but, as is the case with the Math as a Male Domain scale, the meaning of this finding is not clear.

The means on Figure 6 (1.4 to 1.9) imply that students feel they share some qualities with mathematicians, but they do not overlap very much with members of that vocation. A 0 score would have meant equivalence with their stereotype of a mathematician, a 6 vast differences. Because the grade and sex differences are inconsistent, however, it is difficult to interpret these data further. Students become closer to their images of mathematicians from tenth to eleventh grade (Table 3), but the means of Figure 6 for twelfth-graders suggest that trend reverses itself. There are no sex differences in the tenth/eleventh-grade comparison (Table 3), but the sexes do differ in twelfth grade ($t(298) = -4.63$, $p < .001$). This feature of the social milieu as well as the other two do not show as consistent and illuminating effects as the earlier indices of pleasure/displeasure and usefulness.

Figure 6

Distance Between Self-Concept and Stereotype of a Mathematician



Prediction

Many variables were potentially available for multiple regression analyses of Course Plans, but two forms of redundancy needed to be eliminated before such analyses could be done. First, the indicators of ability were highly correlated, as were several of the attitude measures given each year. In order to reduce the redundancy among measures, we constructed a single index of Ability by summing the standardized scores of IQ and mathematics achievement for middle school students, and these two scores plus the Space Relations score for the high school students. Among the attitude measures, we eliminated the single question of Like/Dislike and factor-analyzed the remaining attitude scales using a series of principal components analyses with varimax rotations, one for each grade of students. One central factor contained items from three scales: Easy/Difficult, Enjoyable/Anxiety-Provoking and Creative/Dull. Items which consistently loaded on this factor were summed to create a conglomerate variable called Feelings. A high score indicates a student thinks that mathematics is easy, creative, and not anxiety-provoking. Usefulness items loaded on a factor by themselves as did items on the Math as Open to All/A Male Domain scale and the Distance of Self/Mathematician score. The teacher items from the Support/No Support from Others scale clustered in a fifth factor which was titled Support/No Support from Teachers; the remaining items from this scale were scattered and so were dropped from further analyses. Thus, for each year of testing we defined five attitude variables which could be used with Gender, SES, and Ability to predict Course Plans.

The second form of redundancy was caused by the repeated measurement of students in the three years of the study. Since the attitude scales and the Course Plans measures were given each year, some combinations of variables had to be defined in order to use the maximal amount of information in the

prediction equations. This was accomplished by redefining each variable measured in all three years into three new component parts. The first was an indicator of Level and was defined as the mean for the variable across the three years of testing. The second represented Linear Change and was the difference between the Year 3 and Year 1 scores. The third represented Quadratic Change and was calculated as the Year 1 score plus the Year 3 score minus 2 times the Year 2 score. Level, linear and quadratic change scores were defined for Course Plans, Feelings, and Usefulness, while only level and linear change scores were defined for the social milieu variables since they were only measured in Years 2 and 3 of the study.

The findings from the ordinary least-squares regression analyses appear in Tables 5 and 6. Table 5 summarizes the analyses using only Years 2 and 3 of the data in order to include the maximal set of variables; Table 6 summarizes the analyses using three years of data from all available sources. Additional analyses were done for each sex separately and, where important, are presented in the text, though they do not appear on any table. The presentation is organized to discuss the results for middle school students first, then for high school students.

Middle School Students. In the two-year analyses (Table 5) the level of Course Plans is explained primarily by the level of Feelings one has about mathematics and by one's Gender.

- The first major predictor of the level of students' Course Plans, or, for middle school students, choice of many courses in mathematics over courses in the humanities, is the student's general level of Feelings about mathematics. Students who are more positive about the field more frequently prefer mathematics courses to humanities courses.

Table 5

Prediction Results Using Two Years of Data

	Seventh/Eighth		Tenth/Eleventh	
	Level of Course Plans	Linear Change in Plans	Level of Course Plans	Linear Change in Plans
Level of Feelings	.29***			
Change in Feelings		.32***		
Level of Usefulness				
Change in Usefulness				
Level of Teacher Support				
Change in Teacher Support				
Level of Math as Male Domain				
Change in Math as Male Domain				
Level of Self/Mathematician	n.a.	n.a.		
Change in Self/Mathematician	n.a.	n.a.		
Ability			.30***	
Gender	.28***		.34**	
SES			.10***	
R^2	.42	.26	.45	.07
Number of Students in Analysis	271	271	187	187

** $p \leq .01$; *** $p \leq .001$

- A student's Gender is the other major predictor of level of Course Plans. Males in middle school have a stronger preference for mathematics courses over humanities courses than do females, even after accounting for differences in Feelings, Usefulness, Teacher Support, Math as a Male Domain, Ability, and SES. The number on Table 5 implies that middle school boys who are equivalent to their female classmates on all other predictors score .28 higher on Course Plans than their female classmates. Because this Course Plans variable only ranges from 0 to 3, this difference of slightly more than one quarter of a course is relatively large.

- None of the other predictors in this equation account for a large portion of variance in Course Plans. Usefulness, Teacher Support, Math as a Male Domain, Ability, and SES are not major predictors of level of Course Plans for middle school students. In particular, relatively low ability students and students from working class homes have not ruled out mathematics as a subject to study.

The next analyses are the predictions of change in Course Plans for the seventh/eighth-graders (Table 5). With the sexes together in the equation, only one predictor is significant: changes in Feelings toward mathematics.

- The more a child increases in his/her Feelings about mathematics, the more that child increases in preference for taking mathematics courses. This suggests that an intervention program aimed at increasing participation in mathematics could try to change students' feelings about the difficulty of mathematics or the degree to which it is fun and creative, and expect that changes in preferences for courses would follow along. In addition, since boys' and girls' preferences change in the same way over time, the same method could be used for both sexes.

The separate-sex analyses of linear change in Course Plans over this two-year period show again that changes in Feelings is the primary predictor of changes in Course Plans, but in addition to this variable, the regression for girls demonstrates that a change in Usefulness predicts a change in Course Plans. Thus,

- An intervention program for girls might try to alter their notions of how useful mathematics can be, because this study suggests that girls whose ideas of the usefulness of mathematics blossom tend to want to take more mathematics courses.

The three-year analyses generally support the conclusions from the two-year analyses (Table 6). The single deviation in the prediction of level of Course Plans is in the role of Gender.

- Gender was a significant predictor of level of Course Plans in the two-year analysis, but was not significant when the sixth-grade scores were included. The reason for this may be that Gender has no predictive role in the sixth grade, but only becomes important in the seventh grade. When you add the sixth-grade scores to the data set, they mitigate the role of gender for all three grades.

In addition, these analyses extend the findings about change in Course Plans in that they contain analyses of quadratic as well as linear change.

- Quadratic change in Feelings is a strong predictor of quadratic change in Course Plans, so that changes in Feelings completely track changes in Course Plans. Thus, intervention programs aimed at impacting students' feelings about mathematics may be expected to succeed at changing their preference for mathematics courses.

High School Students. In the analysis of level of Course Plans for the tenth-eleventh graders (Table 5), a different set of predictors act as significant than was true for the younger children. Feelings is irrelevant to Course Plans, but Ability, SES, and Gender are very significant.

- Feelings does not have the same role for the older students as for the younger. The reason for this may be the differences in the measures of Course Plans. In any event, these attitudes toward the subject matter of mathematics do not predict the number of courses high school students say they will take in mathematics departments, while they do predict younger students' preferences for mathematics courses over humanities courses.

- Usefulness and the three measures of the social milieu (Teacher Support, Math as a Male Domain, Distance between Self and Mathematician) are unimportant to the prediction of Course Plans for high school students, as they were for middle school students. At least as they are measured here, these indices of the social milieu do not seem to impact Course Plans.

- Two significant predictors for the older group are Ability and SES. Everything else being equal, high-ability students plan to take more mathematics courses, as do students in higher socioeconomic classes. This is very different from the results for the younger students.

Table 6

Prediction Results Using Three Years of Data

	Sixth/Seventh/Eighth			Ninth/Tenth/Eleventh		
	Level of Course Plans	Linear Change in Plans	Curved Change in Plans	Level of Course Plans	Linear Change in Plans	Curved Change in Plans
Level of Feelings	.26**					
Linear Feelings		.26***				
Curve of Feelings			.34***			
Level of Usefulness						
Linear Usefulness						
Curve of Usefulness						
Ability				.33***		
Gender						
SES				.10***		
R^2	.42	.27	.30	.41	.06	.06
Number of Students in Analysis	271	272[a]	271	187	187	187

** $p \leq .01$; *** $p \leq .001$.

[a]One child lacked Year 2 data on Course Plans, so was not included in the level or curve analyses, but could be included in the linear change analysis.

- Gender also predicts level of Course Plans for high school students. The number in the table implies that boys and girls of equal ability and SES with equivalent attitudes toward mathematics do not enroll in the same number of high school mathematics courses. Boys take .34 more courses than girls. In a possible range of 0 to 3 courses, this is a considerable difference.

The only difference between the separate-sex analyses and the combined-sex analysis is that the SES finding for the group as a whole is only repeated for girls. The general SES finding as stated above needs to be modified.

- Girls from higher SES groups are more likely to want to take a large number of high school mathematics courses, but boys' choice of courses is not as strongly affected by SES. One reason for this difference may be that low SES girls have decided that a business or secretarial track is more desirable and have stopped taking mathematics when it became optional. Low SES boys may not have stopped mathematics for lack of clear options or because the available options (e.g., carpentry, drafting) require an additional year or two.

None of the variables proved to be significant in the prediction of change in Course Plans for high school students.

- For those people interested in intervention programs for high school students, we can offer little advice. Students seem to have typed themselves as "in" or "out" of mathematics according to their ability and SES. Changing their Feelings toward the subject, their knowledge of its Usefulness, or even their social milieu cannot be expected to change their Course Plans.

The three-year analyses of Course Plans deviated in only two ways from the two-year. First, Gender was not a significant predictor of level of Course Plans in the three-year analysis for the high school students, although it was significant in the two-year test. Second, Feelings did not enter the two-year analyses in any significant way, but did enter for boys in the three-year analysis of level of Course Plans. Thus,

- The lack of significance of Gender in the three-year analysis is puzzling. The effect is quite large when only the tenth- and eleventh-grade scores are in the equation, but is not significant when the ninth-grade scores are added. With the middle school students we appealed to a lack of sex differences in Course Plans and most predictors for the sixth-graders, but that is not the case with ninth-graders, for whom many sex differences exist. We can offer the suggestion that the ninth-graders (tested in the fall) had little idea of high school requirements for mathematics and were random in their answers whereas the older students were knowledgeable and consistent.

- Feelings has a much weaker role for high school students than it did for middle school students. It has no role for girls, but does have a small predictive role for boys in the analysis of level of Course Plans.

The analyses of the quadratic change scores indicated that none of the variables was successful at predicting significant quadratic changes in Course Plans. As we found with the linear change analyses of high school students, nothing predicts the changes they make in their number of planned courses in mathematics.

Conclusions

The final step in a project such as this is to translate the results into workable solutions which can reverse the trends so clearly evident with today's students. We need to convince students that mathematics can be enjoyable (a change in many students' present attitudes) and increase their participation in mathematical endeavors.

Five strategies may be proposed from this project:*

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*Please note that some of these make the assumption that regression results yield directional causal conclusions. This leap of faith is justified by the fact that the direction of causality implied in one strategy is reversed in others.

Relax the atmosphere in mathematics classrooms. This is another way of saying: change students' Feelings about mathematics, but aim at the core of these feelings, their reaction to the mathematics classroom. For middle school students this strategy may be expected, if successful, to change students' Feelings and also to change their Course Plans. For high school students we cannot expect that it will change Course Plans, but it will certainly improve the quality of the day-to-day lives of the students.

Present information to students on mathematical careers. Our evidence relevant to such an effort suggests that if it succeeds in changing middle school girls' notion of the usefulness of mathematics, it will also change their Course Plans. While we have no similar evidence of this effect for sixth- to eighth-grade boys and high school students, we can argue that such an effort would still have benefits. For example, few of the students tested had any knowledge of the uses of advanced mathematics outside the classroom. That is, we were not comparing students with such knowledge to those without in our statistical tests. Perhaps such a comparison—which would be possible after an exploration of career options—would show that knowledge of concrete uses for mathematics does influence Course Plans.

Devise special programs for parents, teachers, and guidance counselors on the usefulness of mathematics. Our results showed that parents and teachers generally encourage students in their study of mathematics. While we cannot talk from our results about how this encouragement works, we can at least suggest that if the significant people in a students' world all tell him/her that mathematics is a necessary subject to study, the pressure will be clearly placed on that student to keep trying.

Introduce new non-remedial mathematics courses into the curriculum. For many students in the middle school, making the mathematics class less formal should be sufficient to encourage students in their continued pursuit

of mathematics. But for some sixth- to eighth-graders and for high school students, it may be productive to develop new courses in addition to changing the regular classes' atmosphere. These new courses could aim at teaching a similar curriculum to the traditional courses, but with a different twist. For example, a teacher could try teaching algebra through the medium of social science experiments and statistics or the use of computers. Or perhaps it would be useful to introduce students to non-traditional areas of mathematics such as non-Euclidean geometry or group theory in interesting ways. The idea is that the success students would experience in these new courses might change their notions of their own ability, actually increase their mathematical knowledge, and thus motivate them to re-enter the regular mathematics curriculum or take more courses in mathematics than originally planned.

Require four years of high school mathematics. This study has pointed out the necessity of students' learning mathematics well. It has also shown that there are relationships between some attitudes and Course Plans. Earlier strategies for increasing participation have been based on one interpretation of the results: that changes in attitudes will lead to changes in Course Plans. This strategy is based on the opposite interpretation: that changes in Course Plans will change attitudes, and presumably, better prepare students for the world they will enter after graduation. Quite apart from the results, this strategy can be seen as solving the issue in one blow without recourse to any psychological research.

For a particular school system one strategy may be more appropriate than another or more feasible than another. Whatever the choice, educators need to implement some strategy or strategies to encourage students to take more mathematics. This research suggests that girls have a more serious

need for such programs than boys, but that the same sort of programs will succeed with both sexes. Choices of strategies need to be made now so that students in the 1980's will enroll in the mathematics they need for their future lives.

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APPENDIX A

ENCOURAGING GIRLS IN MATHEMATICS:

THE PROBLEM AND THE SOLUTION

This Appendix is a book manuscript by Lorelei Brush to be published by Abt Associates Press in the spring of 1980.